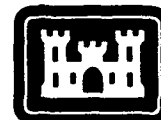


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April 1989

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**US Army Corps  
of Engineers**

Cold Regions Research &  
Engineering Laboratory

## *Influence of well casing composition on trace metals in ground water*

Alan D. Hewitt

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U.S. ARMY TOXIC AND HAZARDOUS MATERIALS AGENCY  
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# Influence of Well Casing Composition on Trace Metals in Ground Water

ALAN D. HEWITT

## INTRODUCTION

Representative ground water sampling requires apparatus made from materials that are chemically inert with respect to the analytes of interest under a variety of environmental conditions. Several materials are being considered by the Environmental Protection Agency (EPA) for use as well casings for ground water monitoring. Four well casing materials now employed were examined in this study: polyvinylchloride (PVC), polytetrafluoroethylene (PTFE), stainless steel 304 (SS304) and stainless steel 316 (SS316).

A review of the literature showed that all of the well casing materials being tested sorb appreciable quantities of certain ion species (Eichholz et al. 1965, Miller 1982). Both natural and contaminated ground water vary widely in composition, so testing a single ground water solution is insufficient (Barcelona et al. 1983). In this study, well casings were exposed to varying concentrations of metals, pH and total organic carbon (TOC) in ground water. The metals selected (arsenic, cadmium, chromium and lead) have been cited by the EPA as priority pollutants.

In previous studies of the effects of well casing composition on inorganic constituents in ground water, it was observed that, in general, steel and stainless steel release metals (Houghton and Berger 1984, Barcelona and Helfrich 1986). The corrosion of stainless steel was also cited as causing a hydrous iron precipitate that could remove species from solution by sorption and coprecipitation (Barcelona and Helfrich 1986). The only laboratory study cited in the literature used deionized water as an aqueous solution, and samples were taken weekly (Miller 1982). Determinations of Cr and Pb showed that the latter was more susceptible to sorption and that PVC was a more active exchange surface than either polyethylene or polypropylene (Miller 1982).

## MATERIALS AND METHODS

This study monitored metal concentrations in a variety of ground water solutions exposed to the four well casing materials. The results were analyzed for trends in sorption and leaching, the effects caused by the variables introduced into the solution, and the randomness of sample pair variability for the analytes tested. The degree to which the analytes were affected was used to rank the casing materials. The test procedure was to submerge samples of well casings in ground water solutions with different metal concentrations, TOC and pH. After 0.5, 4, 8, 24 and 72 hours, aliquots of the solutions were collected for analysis. An increase in the metal concentration would indicate that the well casing material was releasing metals into the solution, while a decrease in concentration would indicate that metals were being sorbed by the casing. Both situations are undesirable.

### Test design

A full  $2^3$  factorial screening experiment was used to test each of the four well casing materials. The variables selected were aqueous metal concentration, pH and TOC. The ground water was obtained from a domestic well system in Weathersfield, Vt. The two added concentrations of metals were the maximum level cited by the EPA for primary drinking water quality and one fifth that concentration (Table 1). Experiments were run both at the natural pH (7.8) and TOC (not determined) of the ground water and at modified levels (pH 5.8, natural TOC plus 5 mg/L humic acid, Aldrich). Acidity was raised by the addition of HCl (reagent grade, Baker), creating an initial pH of 5.8. The natural buffering capacity of the ground water allowed the pH to drift to 6.2 by the end of the 72-hour experiment.

Duplicate samples of each pipe material, along

**Table 1. Aqueous metal concentrations added to ground water for testing well casing materials.**

Metal	High spike* (mg/L)	Low spike (mg/L)
Arsenic	50	10
Cadmium	10	2
Chromium	50	10
Lead	50	10

\* EPA interim primary drinking water standard (1983)

with two controls, were exposed to each set of conditions in the factorial matrix (Fig. 1). Controls consisted of a container and the sample solution without a pipe sample. Replication allows for the measurement of random error (consisting of sample pair variability and analytical precision) and thus confidence levels can be assigned to observed effects. A three-variable factorial has eight sets of variable combinations, creating an experiment with 80 samples (4 materials plus 1 control  $\times$  2 replicates  $\times$  8 conditions). To collect aliquots within 30 minutes, the factorial was blocked, that is, the solutions with high metal concentrations were sampled 2 hours before the samples with low concentrations.

The 80 aqueous solutions were prepared by first adding 97 mL of ground water to each sample container. The condition of high TOC was created by adding 1 mL of 500 mg/L humic acid; no humic acid was added for the low condition. The condition of high acidity (low pH) was created by adding 1 mL of 0.183 M HCl; no acid was added for the low condition. The condition of high metal concentration was created by adding 1 mL of 5 mg/L As, Cr

and Pb and 1 mg/L Cd of mixed metal spike; the condition of low metal concentration was created by adding 1 mL of 1 mg/L As, Cr and Pb and 0.2 mg/L of Cd mixed metal spike. The volume in each sample container was increased to 100 mL with the addition of 1 or 2 mL of reagent-grade water (Milli Q, Millipore Corp.). Pipe sections were the last constituent added to the vessels containing the ground water solutions. All vessels were sealed in a room with no natural light at approximately 24°C. Five aliquots of 2.5 mL each were removed at < 0.5, 4, 8, 24 and 72 hours to produce 400 samples for analysis.

## Materials

Polypropylene 125-mL jars (Model 6185-E37, Thomas Scientific) served as the sample containers. The jars were rinsed and soaked for 24 hours in reagent-grade water prior to use. The PVC and stainless steel well casings were manufactured by Johnson Well Screen, and the PTFE pipe by MIP Inc. All of these pipes were specifically made for ground water monitoring. Approximately 2-cm lengths of 5-cm inner-diameter well casings were cut for the experiment. The exact length of the rings varied with the wall thickness and diameter of the pipe lot tested, maintaining a constant surface area of 80 cm<sup>2</sup>. Cut surfaces made up approximately 17% of the area for the PTFE and PVC well casings but less than 10% for the steels. Care was taken during the milling of the pipe sections to prevent contact with any foreign materials (i.e. grease, dirt, oil, solvents and excessive handling). Individual 2-cm lengths of pipe were rinsed with reagent-grade water and dried before use. No attempt was made to remove surface discoloration or ink present on the pipes due to the manufacturing process. Cleaning of ground monitoring pipes for field applications often consists only of rinsing with the cleanest water available before installation. The pipe sections were completely submersed in the 100 mL of ground water in each container, creating a pipe-surface-area/aqueous-volume ratio of 0.8 cm<sup>-1</sup>. This experimental design has the expected surface/aqueous-solution ratio for well casing at the bottom of the well; however, the ratio is lower than would be encountered at the well screen.

Sample vials (7.5 mL CPE, Nalgene) were cleaned by rinsing with reagent-grade water, soaked for 24 hours in 10% v/v G. Fredrick Smith (GFS) distilled nitric acid, rinsed with reagent-grade water, and air dried. Aliquots (2.5 mL) were transferred to these small vials with an Eppendorf syringe and then immediately acidified to below pH 1 with 50  $\mu$ L of concentrated GFS distilled nitric acid. Studies have

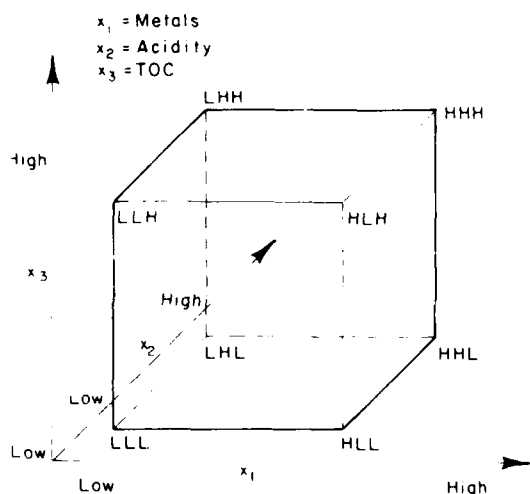


Figure 1. Diagram of factorial matrix.

shown that acidification below pH 1.5 is an effective method for preventing the loss of trace metal species from natural waters (Subramanian et al. 1978).

The experiment and all cleaning operations for the pipe materials and sample containers were performed in class 100 cleanrooms. Ground water, and ground water treated with the spiking solutions of humic acid and HCl, showed no detectable amounts of As, Cd, Cr and Pb at the sensitivity level used for the analysis.

### Instrumentation

Metal concentrations were determined using a Perkin-Elmer (PE) model 703 atomic absorption spectrophotometer coupled with a PE model 2200 heated graphite atomizer. Sample injections of 10 and 20 mL were made with a PE AS-1 autosampler. Each sample aliquot was analyzed at least twice. Analyte concentrations were based on average peak height from strip-chart recordings. Calibration used standards of the same acid composition. Furnace programs and other instrument parameters followed recommended settings for aqueous metal analysis (Perkin-Elmer 1981). Arsenic determinations required deuterium arc background correction to eliminate interferences from the acid in the samples and standards. All metal determinations were completed within three weeks after collecting the sample aliquots. In addition to running aqueous standards with acid concentrations matched to the sample aliquots, EPA trace metal reference standards were analyzed independently to check day-to-day standard preparation.

Conductivity and pH measurements were made on all of the ground water solutions. Acidity was checked at the beginning and end of the 72-hour exposure period (Table 2). All pH measurements

were obtained with a semi-micro glass combination Ross model 81-03 electrode (Orion). The electrode was calibrated with both high and low ionic strength buffers prior to analysis of the ground water solutions. A Leeds and Northrup electrolytic conductivity bridge was used to measure conductivity.

### Aqueous metal spikes

Aqueous metal solutions (As, Cd, Cr and Pb) for standards and sample spikes were made by diluting 1000-mg/L certified atomic absorption reference solutions (Fisher Scientific Corp.). Lead and cadmium were introduced into solution as metals, chromium as potassium dichromate, and arsenic as the trioxide for these reference standards. Mixed metal sample and control spiking solutions without acidification were prepared just prior to doping the ground water. Standards were prepared daily from a separate mixed metal stock. The standard stock solution and working standards were prepared in reagent-grade water (Milli Q) acidified with 2% v/v GFS HNO<sub>3</sub>.

## RESULTS AND DISCUSSION

Ground water was collected and stored in sealed glass bottles for 24 hours prior to making the factorial matrix solutions. From the time of collection to the end of the experiment, shifts in chemical equilibria undoubtedly occurred due to the new environment and added constituents. Once removed from its anoxic environment, ground water may undergo redox and precipitation reactions, such as oxidation of organics, conversion of sulfide to sulfate, and conversion of ferrous iron to ferric with subsequent precipitation of hydrous iron oxides (Stumm and Morgan 1970). Lowering the pH would shift the carbonate equilibrium from predominantly bicarbonate species toward carbon dioxide (Manahan 1972). Clearly these changes could alter the trace metal species distribution. None of these possible changes to the ground water composition were monitored quantitatively.

Qualitatively it was apparent iron was oxidizing on the metal pipes since surface rust developed on the stainless steel in 14 of 32 vessels containing this material (Table 3). In four of the vessels, sufficient oxidation occurred to form a hydrous iron oxide precipitate. Stainless steel 316 was more susceptible to surface oxidation (11 of 16) than SS304 (3 of 16). The hydrous iron oxide precipitate only developed with SS316 in low pH (high acidity) solutions. Rust formed on or near the cut surface of the SS304 pipe, but in the SS316 sections it was predominantly located near the weld on the exterior wall.

**Table 2. Conductivity of ground water solutions and pH measurements at the beginning and end of the 72-hour exposure.**

Matrix no.	Key*	Initial pH	Final pH	Conductance (mho)
1	HHH	5.6	6.1	2.46x10 <sup>-2</sup>
2	HHL	5.6	6.2	2.46x10 <sup>-2</sup>
3	LHH	5.6	6.3	2.42x10 <sup>-2</sup>
4	LHL	5.7	6.2	2.44x10 <sup>-2</sup>
5	HLH	7.7	7.7	1.94x10 <sup>-2</sup>
6	HLL	7.6	7.8	1.92x10 <sup>-2</sup>
7	LLH	7.9	7.9	1.98x10 <sup>-2</sup>
8	LLL	7.7	7.9	1.96x10 <sup>-2</sup>

\*Key

Order: Metal, acidity, TOC

H = High

L = Low

**Table 3. Physical state of stainless steel pipes after 72 hours of exposure to ground water solutions.**

	HHH*	HHL	LHH	LHL	HLH	HLL	LLH	LLL
SS304	O/E	O/E	—	—	—	—	—	—
SS304	—	—	O/E	—	—	—	—	—
SS316	F/E	—	—	F/W	O/W	O/W	O/W	O/E
SS316	F/W	F/E	—	—	O/W	O/W	—	O/W

\* See Table 2

KEY: O - oxidation on surface

F - hydrous iron oxide precipitate in solution

E - oxidation near edge

W - oxidation on wall

**Table 4. Design matrix for 2<sup>3</sup> factorial run in duplicate (−1 represents the low level and +1 the high level of each variable).**

	X <sub>1</sub>	X <sub>2</sub>	X <sub>3</sub>	X <sub>1</sub> X <sub>2</sub>	X <sub>1</sub> X <sub>3</sub>	X <sub>2</sub> X <sub>3</sub>	X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	Y*
LLL	−1	−1	−1	+1	+1	+1	−1	24.3
LLL	−1	−1	−1	+1	+1	+1	−1	20.9
HLL	+1	−1	−1	−1	−1	+1	+1	27.8
HLL	+1	−1	−1	−1	−1	+1	+1	27.8
LHL	−1	+1	−1	−1	+1	−1	+1	56.1
LHL	−1	+1	−1	−1	+1	−1	+1	56.1
HHL	+1	+1	−1	+1	−1	−1	−1	61.6
HHL	+1	+1	−1	+1	−1	−1	−1	49.6
LLH	−1	−1	+1	+1	−1	−1	+1	54.9
LLH	−1	−1	+1	+1	−1	−1	+1	53.1
HLH	+1	−1	+1	−1	+1	−1	−1	50.2
HLH	+1	−1	+1	−1	+1	−1	−1	50.2
LHH	−1	+1	+1	−1	−1	+1	−1	96.3
LHH	−1	+1	+1	−1	−1	+1	−1	85.2
HHH	+1	+1	+1	+1	+1	+1	+1	73.7
HHH	+1	+1	+1	+1	+1	+1	+1	73.7

\* Example of normalized responses, Pb - SS304 - 24 hours.

KEY: X<sub>1</sub> = Metal concentration

X<sub>2</sub> = Acidity

X<sub>3</sub> = TOC.

**Table 5. ANOVA for Pb at 24 hours with SS304 well casing. The average normalized response was 53.8 and the standard deviation was 4.2.**

Factor	Effects	df	MS	F	Sig.*
X <sub>1</sub> (Metal conc.)	−4.04	1		3.70	NS
X <sub>2</sub> (Acidity)	30.4	1		209	VS
X <sub>3</sub> (TOC)	26.6	1		161	VS
X <sub>1</sub> X <sub>2</sub>	−4.74	1		5.09	NS
X <sub>1</sub> X <sub>3</sub>	−6.39	1		9.26	S
X <sub>2</sub> X <sub>3</sub>	−0.26	1		0.02	NS
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	−1.89	1		0.81	NS
ERROR	39.7	8	17.6		

\*S = significant effect at a significance level of 5%

VS = very significant, order of magnitude greater than F value [ $F_{0.95}(df 1,8) = 5.32$ ] at a significance level of 5%

NS = not a significant effect at 5% level.

Aqueous metal concentrations for the vessels containing well casing pipe sections were compared to the average amount determined in the two controls within each matrix set and multiplied by 100. Handling the data in this fashion normalized the metal concentrations observed for the two levels tested, allowing an analysis of variance (ANOVA) on the entire data set. Consequently the expected value in every case would be 100 if the pipe casing exerted no influence.

An ANOVA was performed on a matrix of eight duplicates for each time interval (Table 4). A representative ANOVA table containing all computed effects, mean squares and F-ratios appears in Table 5. The complete array of ANOVA tables is given in Appendix A. Typically interaction effects are small compared to main effects. Consequently the data summaries that follow will be based exclusively on main effects and trends in those effects as a function of time. The average response is based on all 16 measurements in a set. Each effect is the average of the eight responses when a variable is at the high setting minus the average of the eight responses at the low settings. The MS error is simply the sum of squares for error between the replicates divided by eight degrees of freedom (df) (one df from each pair of values). The standard deviation is the square root of the MS and represents the random error associated with an individual experiment.

Table 6 summarizes the effects noted in ANOVA for the aqueous metal concentrations in contact with the four pipe materials. Since sample aliquots were taken at five separate time intervals, effects that followed a pattern provided support for the analysis of variance conclusions. Effects were established at the 95% confidence level. The effects shown in Table 6 represent the influence that the matrix variables have on the analyte concentration when a single constituent changes from the low to the high level. The last two columns in this table show the random error variance associated with the duplicate determinations. The standard deviation was obtained by taking the square root of the mean sums of squares for the error. The larger this term becomes, the less likely that the analysis will be able to distinguish real effects from random variations. Standard deviations greater than 10% depict large random discrepancies between sample pairs.

#### Arsenic

No consistent pattern of effects was observed by the ANOVA on the aqueous arsenic concentrations. In general PTFE and PVC showed no change in concentration throughout the 72-hour exposure period. The lack of influence may be due to the



**Table 6. Summary of significant ( $\alpha = 0.05$ ) main effects and the random error of measurement for the four metals. The standard deviation given here is the square root of the MS error and represents the random error associated with an individual measurement.**

Time (hr)	Pipe	Average response	Metal $X_1$	Acidity $X_2$	TOC $X_3$	MS error	Standard deviation
Arsenic							
0.5	PVC	99.1		-2.6		14.8	3.8
	PTFE	99.9				24.9	5.0
	SS304	99.7				33.4	5.7
	SS316	99.4				16.0	4.0
4.0	PVC	102	+2.8			20.4	4.5
	PTFE	99.3				27.4	5.2
	SS304	97.8				40.4	6.3
	SS316	94.5				36.6	6.0
8.0	PVC	100		-4.3		45.1	4.5
	PTFE	101				96.3	9.8
	SS304	96.2				32.3	5.7
	SS316	94.5				46.0	6.8
24.0	PVC	99.4			-3.8	40.8	6.4
	PTFE	99.2				28.9	5.4
	SS304	89.4				26.3	5.1
	SS316	85.3				63.7	8.0
72.0	PVC	103		-5.9		21.4	4.6
	PTFE	102				20.2	4.5
	SS304	89.1				70.9	8.4
	SS316	87.4				68.4	8.3
Cadmium							
0.5	PVC	101	-3.3	-1.2	-2.6	6.06	2.5
	PTFE	101			-1.2	1.28	1.1
	SS304	106			-2.5	12.9	3.6
	SS316	104			-2.7	4.47	2.1
4.0	PVC	113	-7.1	+9.2		13.9	3.7
	PTFE	103				29.3	5.4
	SS304	117				217	15
	SS316	124				2428	49
8.0	PVC	115	-8.5	+14.2	-2.4	14.0	3.7
	PTFE	103				2.42	1.6
	SS304	116				207	14
	SS316	130				2207	47
24.0	PVC	116	-12.5	+14.5	-4.4	31.4	5.6
	PTFE	103				2.90	1.7
	SS304	112				147	12
	SS316	136				4614	68
72.0	PVC	114	-14.5	+14.9		24.5	4.9
	PTFE	102				4.86	2.2
	SS304	103				186	14
	SS316	1254				4419	66
Chromium							
0.5	PVC	101				3.34	1.8
	PTFE	101				0.51	0.7
	SS304	101				2.61	1.6
	SS316	102				2.12	1.5

**Table 6 (cont'd). Summary of significant ( $\alpha = 0.05$ ) main effects and the random error of measurement for the four metals. The standard deviation given here is the square root of the MS error and represents the random error associated with an individual measurement.**

Time (hr)	Pipe	Average response	Metal $X_1$	Acidity $X_2$	TOC $X_3$	MS error	Standard deviation
4.0	PVC	99.9				1.71	1.3
	PTFE	101	+0.75		+0.75	1.16	1.1
	SS304	95.7		-3.55		13.8	3.7
	SS316	92.1	-3.2	-5.1	+5.0	27.6	5.2
8.0	PVC	100				1.96	1.4
	PTFE	98.9	-1.6			3.64	1.9
	SS304	97.2				251	16
	SS316	87.2	-7.0	-7.8	+5.8	102	10
24.0	PVC	100		-1.4		2.57	1.6
	PTFE	101	+1.9			5.67	2.4
	SS304	103				1381	37
	SS316	85.5		-11.2	+8.7	118	11
72.0	PVC	101	+1.3			3.35	1.8
	PTFE	100	+1.8			1.62	1.3
	SS304	103				1795	42
	SS316	83.6		-11.3	+9.4	98.6	9.9
				<b>Lead</b>			
0.5	PVC	99.9		-0.55		0.82	0.9
	PTFE	100				6.53	2.6
	SS304	102				0.64	0.8
	SS316	101				6.49	2.5
4.0	PVC	88.9		-2.2	+2.9	9.19	3.0
	PTFE	97.4	+1.6			3.69	1.9
	SS304	78.4	-2.2	+6.8	+6.4	12.1	3.5
	SS316	80.3	-5.5	+7.2	+7.4	59.7	7.7
8.0	PVC	89.3			+3.7	12.4	3.5
	PTFE	98.5		+1.9		9.98	3.2
	SS304	69.9	-3.4	+12.1	+9.0	9.61	3.1
	SS316	80.4	-7.7	+10.8	+9.7	100	10
24.0	PVC	80.8		-5.4	+6.9	25.7	5.1
	PTFE	95.1			+2.4	16.2	4.0
	SS304	53.8		+15.2	+13.3	17.6	4.2
	SS316	79.3	-10.7		+14.8	351	19
72.0	PVC	74.3		-5.9	+9.6	41.4	6.4
	PTFE	89.9	+3.0	-2.2	+4.1	11.5	3.4
	SS304	45.2		+15.7	+12.4	37.3	6.1
	SS316	72.0		+16.3	+18.0	2936	17

preferred state of this metal in aqueous solution. Arsenic exists as arsenates ( $\text{H}_3\text{AsO}_4$ ,  $\text{H}_2\text{AsO}_4^-$  and  $\text{HAsO}_4^{2-}$ ) under oxidizing conditions and as arsenites ( $\text{H}_3\text{AsO}_3$ ,  $\text{H}_2\text{AsO}_3^-$  and  $\text{HASO}_3^{2-}$ ) under moderate reducing conditions in natural waters (Fowler et al. 1979). These partly dissociated species are negatively charged and are not likely to interact with

surfaces such as plastics, which are better known for their cation exchange capabilities (Massee and Maessen 1981). The vessels containing both types of stainless steel showed, on the average, about a 10% decrease in aqueous arsenic relative to the controls for the two longest exposures.

## Cadmium

On the average, aqueous cadmium concentration increased relative to the controls for all pipe sections except PTFE, which showed no consistent effects and no change in aqueous cadmium concentration. PVC in general showed a constant 15% average enrichment in cadmium after 4 hours of exposure. This enrichment was affected negatively by the concentration of the initial metal spike (the percentage of cadmium enrichment was less at 10 mg/L than at 2 mg/L; however, the absolute amount of Cd contributed by the pipe was approximately 0.5 mg/L in both solutions) and positively by hydrogen ion (cadmium concentration increased as hydrogen ion concentration increased). Increasing TOC showed a very small and inconsistent negative effect. Stainless steel 304 showed an average 15% increase in cadmium for the 4-, 8- and 24-hour aliquots; however, it returned to the same level as the control for the last collection. This material was also affected by the concentration of the metal spike (negative) and hydrogen ion (positive).

A similar pattern was observed for SS316 except that it did not return all the way to the control level after 72 hours and the effects were less consistent due to large random errors. For all the pipe materials that showed enrichment of cadmium, a maximum was reached before 72 hours of exposure, and the effect was most prominent at low metal concentration and high hydrogen ion concentration (low pH). This suggests that the release of cadmium to solution from PVC, SS304 and SS316 was small and that some sorption occurred with time. Cadmium may have been employed as a UV stabilizer during the manufacturing of PVC (Wilson et al. 1982), and it may exist as an impurity in stainless steel.

The standard deviation for SS304 was greater than 10%, showing large random discrepancies between sample duplicates. Random variation was a dominant feature with SS316, where after 4 hours of exposure the standard deviation was greater than 47%. In sample duplicates the presence of a single SS316 pipe section with surface oxidation was the major source of variance. In contrast the standard deviation for both PVC and PTFE were consistently below 6%.

## Chromium

PTFE, PVC and SS304 showed no consistent effects and on the average no change in aqueous chromium relative to the controls. The lack of interaction with plastic may be due to the salt of the metal employed to make the aqueous solutions. Potassium dichromate in solution predominantly exists as dichromate and chromate ( $\text{Cr}_2\text{O}_7^{2-}$ ,  $\text{CrO}_4^{2-}$ ). Negatively

charged species are not as likely to exchange with plastic surfaces.

Stainless steel 316 showed a 16% average reduction in chromium after 72 hours of exposure. This response was affected by the concentration of hydrogen ion (negative) and TOC (positive). The standard deviation reached 10% after 8 hours for SS316. At the lower pH there was increased surface oxidation with regard to SS316, which may have created sorption sites and consequently increased random variation. Humic species increased the stability of aqueous chromium, perhaps by acting as a complexing agent. The standard deviation for SS304 steadily increased from 3.7% at 4 hours to 42% by 72 hours. Again the pairs with the greatest discrepancies had one member with surface oxidation. In general, surface oxidation appeared to be a chromium source with SS304 and a sink with SS316.

## Lead

All four pipe materials showed a continuous loss of aqueous lead relative to the controls with time (Fig. 2). This metal was by far the most active species in terms of sorbing onto the well casing surfaces. PTFE had the least-active surface, followed by PVC, SS316 and SS304. The average losses ranged from 10% for PTFE to 55% for SS304 after 72 hours of exposure. No effects were either large or consistent with respect to solutions in contact with PTFE. For SS316, there were large effects that were significant when they were consistent but that were sometimes not statistically significant due to large random error. The trend was toward negative effects for metal concentration and positive effects for hydrogen ion and TOC concentration. Aqueous concentrations of lead in contact with both PVC and SS304 were consistently affected by matrix variables. TOC

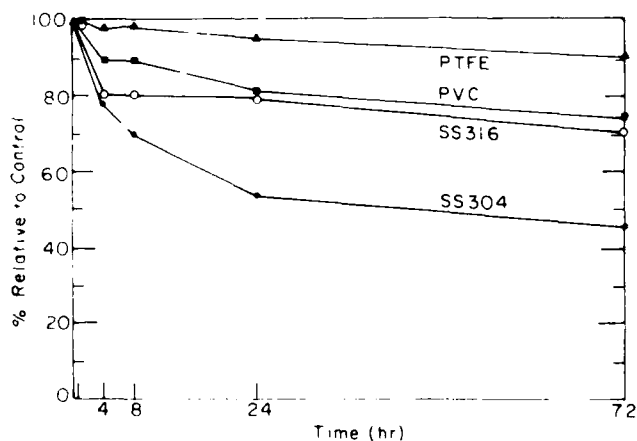


Figure 2. Relative loss of lead in solutions exposed to well casings.

concentration showed a positive influence on aqueous lead concentrations in the presence of PVC and SS304 pipe sections. Stainless steel 304 was also affected positively by the concentration of hydrogen ion. Humic material apparently again acted as a complexing agent, making lead more stable in solution. Lower pH also increased the ability of lead to remain in solution for the vessels containing SS304. Acidity was increased in the ground water solutions by the addition of HCl; with this species in solution, hydrogen ions may compete for sorption sites.

## CONCLUSION

In laboratory testing, SS316 and SS304 were found susceptible to oxidation at locations near cuts and welds in ground water solutions. Surface oxidation, presumably by galvanic action, provides active sites for sorption and also releases impurities and major constituents. This random source of error most likely depends on the specific production batch and supplier of the well casing pipe. Installation is also an important variable since any abrasions would readily act as oxidation sites. Stainless steel sorbed both anions and cations faster than PVC or PTFE. Therefore, stainless steels are prone to imposing specific signatures on ground water and are not suitable where trace metal determinations are planned.

PVC was a source for low levels of cadmium and it acts as a moderately active surface for the sorption of lead. Both of these processes were affected by the ground water composition. Lead was affected positively by increasing the TOC concentration, and the effect on cadmium depended on the analyte concentration. Regardless, PVC should be considered as a well casing candidate based on economics (PVC is one sixth the price of PTFE) and the strong possibility that the effects cited previously are of less concern at well recharge rates of less than 24 hours. PTFE showed no marked interactions with any of the metals tested. This material is superior to the others because it did not influence trace inorganics in ground water of various compositions.

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## APPENDIX A: ANOVA TABLES FOR ALL RESULTS

The significance levels are the same as in Table 5

Table A1. ANOVA for As at 0.5 hours with PVC well casing. The average normalized response was 99.1 and the standard deviation was 3.8.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	-3.26	1	2.87	NS	
X <sub>2</sub> (Acidity)	-5.14	1	7.11	S	
X <sub>3</sub> (TOC)	3.49	1	3.27	NS	
X <sub>1</sub> X <sub>2</sub>	-3.01	1	2.45	NS	
X <sub>1</sub> X <sub>3</sub>	1.26	1	0.43	NS	
X <sub>2</sub> X <sub>3</sub>	-3.21	1	2.78	NS	
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	-1.74	1	0.81	NS	
Error		8	14.8		

Table A2. ANOVA for As at 4 hours with PVC well casing. The average normalized response was 102 and the standard deviation was 4.5.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	5.70	1	6.35	S	
X <sub>2</sub> (Acidity)	-3.85	1	2.90	NS	
X <sub>3</sub> (TOC)	-0.82	1	0.13	NS	
X <sub>1</sub> X <sub>2</sub>	0.90	1	0.16	NS	
X <sub>1</sub> X <sub>3</sub>	5.78	1	6.52	S	
X <sub>2</sub> X <sub>3</sub>	-7.22	1	10.2	S	
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	-2.87	1	1.62	NS	
Error		8	20.5		

Table A3. ANOVA for As at 8 hours with PVC well casing. The average normalized response was 100 and the standard deviation was 6.7.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	2.18	1	0.42	NS	
X <sub>2</sub> (Acidity)	-1.32	1	0.16	NS	
X <sub>3</sub> (TOC)	-4.02	1	1.44	NS	
X <sub>1</sub> X <sub>2</sub>	-0.22	1	0.00	NS	
X <sub>1</sub> X <sub>3</sub>	-1.02	1	0.09	NS	
X <sub>2</sub> X <sub>3</sub>	-0.08	1	0.00	NS	
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	-5.22	1	2.42	NS	
Error		8	45.1		

Table A4. ANOVA for As at 24 hours with PVC well casing. The average normalized response was 99.4 and the standard deviation was 6.4.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	-1.75	1	0.30	NS	
X <sub>2</sub> (Acidity)	0.00	1	0.00	NS	
X <sub>3</sub> (TOC)	0.55	1	0.03	NS	
X <sub>1</sub> X <sub>2</sub>	1.88	1	0.34	NS	
X <sub>1</sub> X <sub>3</sub>	-4.42	1	1.92	NS	
X <sub>2</sub> X <sub>3</sub>	1.88	1	0.34	NS	
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	-0.85	1	0.07	NS	
Error		8	40.8		

Table A5. ANOVA for As at 72 hours with PVC well casing. The average normalized response was 103 and the standard deviation was 4.6.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	-4.84	1	4.37	NS	
X <sub>2</sub> (Acidity)	-3.96	1	2.93	NS	
X <sub>3</sub> (TOC)	-2.94	1	1.61	NS	
X <sub>1</sub> X <sub>2</sub>	-1.09	1	0.22	NS	
X <sub>1</sub> X <sub>3</sub>	2.74	1	1.40	NS	
X <sub>2</sub> X <sub>3</sub>	0.46	1	0.04	NS	
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	0.54	1	0.05	NS	
Error		8	21.4		

Table A6. ANOVA for As at 0.5 hours with PTFE well casing. The average normalized response was 99.9 and the standard deviation was 5.0.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	-2.30	1	0.85	NS	
X <sub>2</sub> (Acidity)	0.70	1	0.08	NS	
X <sub>3</sub> (TOC)	-0.65	1	0.07	NS	
X <sub>1</sub> X <sub>2</sub>	-2.32	1	0.87	NS	
X <sub>1</sub> X <sub>3</sub>	2.28	1	0.83	NS	
X <sub>2</sub> X <sub>3</sub>	2.22	1	0.80	NS	
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	-1.40	1	3.32	NS	
Error		8	24.9		

Table A7. ANOVA for As at 4 hours with PTFE well casing. The average normalized response was 99.3 and the standard deviation was 5.2.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	5.20	1	3.90	NS	
X <sub>2</sub> (Acidity)	4.50	1	2.92	NS	
X <sub>3</sub> (TOC)	-2.40	1	0.93	NS	
X <sub>1</sub> X <sub>2</sub>	3.38	1	1.64	NS	
X <sub>1</sub> X <sub>3</sub>	1.88	1	0.51	NS	
X <sub>2</sub> X <sub>3</sub>	-0.67	1	0.07	NS	
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	0.45	1	0.03	NS	
Error		8	27.7		

Table A8. ANOVA for As at 8 hours with PTFE well casing. The average normalized response was 101 and the standard deviation was 9.8.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	2.45	1	1.99	NS	
X <sub>2</sub> (Acidity)	0.45	1	0.07	NS	
X <sub>3</sub> (TOC)	-2.62	1	2.29	NS	
X <sub>1</sub> X <sub>2</sub>	0.08	1	0.00	NS	
X <sub>1</sub> X <sub>3</sub>	-7.70	1	19.7	S	
X <sub>2</sub> X <sub>3</sub>	-5.26	1	9.16	S	
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	-5.32	1	9.42	S	
Error		8	12.0		

Table A9. ANOVA for As at 24 hours with PTFE well casing. The average normalized response was 99.2 and the standard deviation was 5.4.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	2.26	1		0.71	NS
X <sub>2</sub> (Acidity)	-1.29	1		0.23	NS
X <sub>3</sub> (TOC)	-7.71	1		8.21	S
X <sub>1</sub> X <sub>2</sub>	2.73	1		1.04	NS
X <sub>1</sub> X <sub>3</sub>	-3.79	1		1.98	NS
X <sub>2</sub> X <sub>3</sub>	0.81	1		0.09	NS
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	-1.36	1		0.26	NS
Error		8	29.0		

Table A10. ANOVA for As at 72 hours with PTFE well casing. The average normalized response was 102 and the standard deviation was 4.5.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	-4.56	1		4.11	NS
X <sub>2</sub> (Acidity)	-1.56	1		0.48	NS
X <sub>3</sub> (TOC)	-1.56	1		0.48	NS
X <sub>1</sub> X <sub>2</sub>	6.26	1		7.75	S
X <sub>1</sub> X <sub>3</sub>	3.11	1		1.92	NS
X <sub>2</sub> X <sub>3</sub>	5.71	1		6.45	S
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	-2.11	1		0.88	NS
Error		8	20.2		

Table A11. ANOVA for As at 0.5 hours with SS304 well casing. The average normalized response was 99.7 and the standard deviation was 5.7.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	2.62	1		0.82	NS
X <sub>2</sub> (Acidity)	-2.40	1		0.69	NS
X <sub>3</sub> (TOC)	1.98	1		0.47	NS
X <sub>1</sub> X <sub>2</sub>	-2.05	1		0.50	NS
X <sub>1</sub> X <sub>3</sub>	1.62	1		0.32	NS
X <sub>2</sub> X <sub>3</sub>	-1.85	1		0.41	NS
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	0.70	1		0.06	NS
Error		8	33.4		

Table A12. ANOVA for As at 4 hours with SS304 well casing. The average normalized response was 97.8 and the standard deviation was 6.3.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	-2.12	1		0.44	NS
X <sub>2</sub> (Acidity)	-1.95	1		0.38	NS
X <sub>3</sub> (TOC)	-2.70	1		0.72	NS
X <sub>1</sub> X <sub>2</sub>	-1.25	1		0.15	NS
X <sub>1</sub> X <sub>3</sub>	2.65	1		0.70	NS
X <sub>2</sub> X <sub>3</sub>	-4.72	1		2.21	NS
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	-0.88	1		0.08	NS
Error		8	40.4		

Table A13. ANOVA for As at 8 hours with SS304 well casing. The average normalized response was 96.2 and the standard deviation was 5.7.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	-5.09	1		3.20	NS
X <sub>2</sub> (Acidity)	-8.59	1		9.12	S
X <sub>3</sub> (TOC)	-3.74	1		1.73	NS
X <sub>1</sub> X <sub>2</sub>	-4.46	1		2.46	NS
X <sub>1</sub> X <sub>3</sub>	2.79	1		0.96	NS
X <sub>2</sub> X <sub>3</sub>	2.54	1		0.80	NS
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	-10.5	1		13.7	S
Error		8	32.3		

Table A14. ANOVA for As at 24 hours with SS304 well casing. The average normalized response was 89.4 and the standard deviation was 5.1.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	-0.56	1		0.05	NS
X <sub>2</sub> (Acidity)	-1.96	1		0.59	NS
X <sub>3</sub> (TOC)	-2.89	1		1.27	NS
X <sub>1</sub> X <sub>2</sub>	-3.09	1		1.45	NS
X <sub>1</sub> X <sub>3</sub>	4.04	1		2.48	NS
X <sub>2</sub> X <sub>3</sub>	7.29	1		8.09	S
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	-1.39	1		0.29	NS
Error		8	26.3		

Table A15. ANOVA for As at 72 hours with SS304 well casing. The average normalized response was 89.1 and the standard deviation was 8.4.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	-8.80	1		4.37	NS
X <sub>2</sub> (Acidity)	-11.7	1		7.75	S
X <sub>3</sub> (TOC)	-4.15	1		0.97	NS
X <sub>1</sub> X <sub>2</sub>	-13.6	1		10.5	S
X <sub>1</sub> X <sub>3</sub>	23.0	1		30.0	S
X <sub>2</sub> X <sub>3</sub>	8.02	1		3.63	NS
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	1.62	1		0.14	NS
Error		8	70.9		

Table A16. ANOVA for As at 0.5 hours with SS316 well casing. The average normalized response was 99.4 and the standard deviation was 4.0.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	-4.12	1		4.25	NS
X <sub>2</sub> (Acidity)	-2.75	1		1.89	NS
X <sub>3</sub> (TOC)	2.20	1		1.21	NS
X <sub>1</sub> X <sub>2</sub>	2.30	1		1.32	NS
X <sub>1</sub> X <sub>3</sub>	1.45	1		0.52	NS
X <sub>2</sub> X <sub>3</sub>	-2.18	1		1.18	NS
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	-0.68	1		0.11	NS
Error		8	16.0		

Table A17. ANOVA for As at 4 hours with SS316 well casing. The average normalized response was 91.5 and the standard deviation was 6.0.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	3.52	1		1.34	NS
X <sub>2</sub> (Acidity)	3.80	1		1.58	NS
X <sub>3</sub> (TOC)	-2.35	1		0.62	NS
X <sub>1</sub> X <sub>2</sub>	-0.75	1		0.06	NS
X <sub>1</sub> X <sub>3</sub>	7.60	1		6.32	S
X <sub>2</sub> X <sub>3</sub>	-2.62	1		0.75	NS
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	-2.62	1		0.75	NS
Error		8	36.6		

Table A18. ANOVA for As at 8 hours with SS316 well casing. The average normalized response was 94.5 and the standard deviation was 6.8.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	2.55	1		0.57	NS
X <sub>2</sub> (Acidity)	-1.35	1		0.16	NS
X <sub>3</sub> (TOC)	-9.10	1		7.20	S
X <sub>1</sub> X <sub>2</sub>	-0.82	1		0.06	NS
X <sub>1</sub> X <sub>3</sub>	8.28	1		5.95	S
X <sub>2</sub> X <sub>3</sub>	-7.02	1		4.29	NS
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	-7.55	1		4.95	NS
Error		8	46.0		

Table A19. ANOVA for As at 24 hours with SS316 well casing. The average normalized response was 85.3 and the standard deviation was 8.0.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	0.05	1		0.00	NS
X <sub>2</sub> (Acidity)	1.58	1		0.16	NS
X <sub>3</sub> (TOC)	2.55	1		0.41	NS
X <sub>1</sub> X <sub>2</sub>	-0.60	1		0.02	NS
X <sub>1</sub> X <sub>3</sub>	5.32	1		1.78	NS
X <sub>2</sub> X <sub>3</sub>	1.39	1		0.11	S
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	1.52	1		0.15	NS
Error		8	63.7		

Table A20. ANOVA for As at 72 hours with SS316 well casing. The average normalized response was 87.4 and the standard deviation was 8.3.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	3.69	1		0.79	NS
X <sub>2</sub> (Acidity)	7.74	1		3.50	NS
X <sub>3</sub> (TOC)	-7.63	1		3.41	NS
X <sub>1</sub> X <sub>2</sub>	-8.51	1		4.23	NS
X <sub>1</sub> X <sub>3</sub>	14.6	1		12.4	S
X <sub>2</sub> X <sub>3</sub>	-0.94	1		0.05	NS
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	5.66	1		1.87	NS
Error		8	68.4		

Table A21. ANOVA for Cd at 0.5 hours with PVC well casing. The average normalized response was 101 and the standard deviation was 2.5.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	-2.49	1		4.08	NS
X <sub>2</sub> (Acidity)	-2.71	1		4.85	NS
X <sub>3</sub> (TOC)	-5.13	1		17.4	S
X <sub>1</sub> X <sub>2</sub>	-1.19	1		0.93	NS
X <sub>1</sub> X <sub>3</sub>	-0.91	1		0.54	NS
X <sub>2</sub> X <sub>3</sub>	0.41	1		0.11	NS
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	-1.11	1		0.82	NS
Error		8	6.06		

Table A22. ANOVA for Cd at 4 hours with PVC well casing. The average normalized response was 113 and the standard deviation was 3.7.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	-14.2	1		58.1	VS
X <sub>2</sub> (Acidity)	18.4	1		97.1	VS
X <sub>3</sub> (TOC)	-1.90	1		1.04	NS
X <sub>1</sub> X <sub>2</sub>	-9.70	1		27.1	S
X <sub>1</sub> X <sub>3</sub>	3.95	1		4.50	NS
X <sub>2</sub> X <sub>3</sub>	-0.35	1		0.04	NS
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	-0.10	1		0.00	NS
Error		8	13.9		

Table A23. ANOVA for Cd at 8 hours with PVC well casing. The average normalized response was 115 and the standard deviation was 3.7.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	-19.0	1		103	VS
X <sub>2</sub> (Acidity)	28.4	1		230	VS
X <sub>3</sub> (TOC)	-4.85	1		6.70	S
X <sub>1</sub> X <sub>2</sub>	-12.6	1		45.4	S
X <sub>1</sub> X <sub>3</sub>	6.70	1		12.8	S
X <sub>2</sub> X <sub>3</sub>	-4.48	1		5.70	S
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	4.42	1		5.57	S
Error		8	14.1		

Table A24. ANOVA for Cd at 24 hours with PVC well casing. The average normalized response was 116 and the standard deviation was 5.6.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	-25.0	1		79.8	VS
X <sub>2</sub> (Acidity)	29.0	1		107	VS
X <sub>3</sub> (TOC)	-8.82	1		9.93	S
X <sub>1</sub> X <sub>2</sub>	-17.0	1		36.9	S
X <sub>1</sub> X <sub>3</sub>	9.52	1		11.6	S
X <sub>2</sub> X <sub>3</sub>	-10.6	1		14.4	S
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	8.02	1		8.21	S
Error		8	31.4		

Table A25. ANOVA for Cd at 72 hours with PVC well casing. The average normalized response was 114 and the standard deviation was 4.9.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	-29.1	1	137		VS
X <sub>2</sub> (Acidity)	29.8	1	144		VS
X <sub>3</sub> (TOC)	0.39	1	0.02		NS
X <sub>1</sub> X <sub>2</sub>	-20.0	1	65.2		VS
X <sub>1</sub> X <sub>3</sub>	12.3	1	24.7		S
X <sub>2</sub> X <sub>3</sub>	-7.86	1	10.1		S
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	7.21	1	8.47		S
Error		8	24.6		

Table A26. ANOVA for Cd at 0.5 hours with PTFE well casing. The average normalized response was 101 and the standard deviation was 1.1.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	0.46	1	0.67		NS
X <sub>2</sub> (Acidity)	-2.43	1	18.5		S
X <sub>3</sub> (TOC)	-2.44	1	18.5		S
X <sub>1</sub> X <sub>2</sub>	-1.04	1	3.36		NS
X <sub>1</sub> X <sub>3</sub>	1.66	1	8.62		S
X <sub>2</sub> X <sub>3</sub>	0.31	1	0.30		NS
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	1.51	1	7.14		S
Error		8	1.28		

Table A27. ANOVA for Cd at 4 hours with PTFE well casing. The average normalized response was 103 and the standard deviation was 5.4.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	-1.74	1	0.41		NS
X <sub>2</sub> (Acidity)	0.91	1	0.11		NS
X <sub>3</sub> (TOC)	-0.04	1	0.00		NS
X <sub>1</sub> X <sub>2</sub>	0.96	1	0.12		NS
X <sub>1</sub> X <sub>3</sub>	2.66	1	0.97		NS
X <sub>2</sub> X <sub>3</sub>	1.56	1	0.33		NS
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	-4.09	1	2.28		NS
Error		8	29.3		

Table A28. ANOVA for Cd at 8 hours with PTFE well casing. The average normalized response was 103 and the standard deviation was 1.6.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	3.15	1	16.4		S
X <sub>2</sub> (Acidity)	3.65	1	22.1		S
X <sub>3</sub> (TOC)	-0.75	1	0.93		NS
X <sub>1</sub> X <sub>2</sub>	3.70	1	22.7		S
X <sub>1</sub> X <sub>3</sub>	-0.70	1	0.81		NS
X <sub>2</sub> X <sub>3</sub>	0.30	1	0.15		NS
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	-2.45	1	9.94		S
Error		8	2.42		

Table A29. ANOVA for Cd at 24 hours with PTFE well casing. The average normalized response was 103 and the standard deviation was 1.7.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	-0.34	1	0.15		NS
X <sub>2</sub> (Acidity)	1.86	1	4.79		NS
X <sub>3</sub> (TOC)	-3.16	1	13.8		S
X <sub>1</sub> X <sub>2</sub>	4.56	1	28.8		S
X <sub>1</sub> X <sub>3</sub>	1.74	1	4.17		NS
X <sub>2</sub> X <sub>3</sub>	-5.86	1	47.5		S
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	2.14	1	6.31		S
Error		8	2.90		

Table A30. ANOVA for Cd at 72 hours with PTFE well casing. The average normalized response was 102 and the standard deviation was 2.2.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	-3.92	1	12.7		S
X <sub>2</sub> (Acidity)	0.90	1	0.67		NS
X <sub>3</sub> (TOC)	0.78	1	0.49		NS
X <sub>1</sub> X <sub>2</sub>	-1.65	1	2.24		NS
X <sub>1</sub> X <sub>3</sub>	-2.18	1	3.89		NS
X <sub>2</sub> X <sub>3</sub>	1.75	1	2.52		NS
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	-0.90	1	0.67		NS
Error		8	4.86		

Table A31. ANOVA for Cd at 0.5 hours with SS304 well casing. The average normalized response was 106 and the standard deviation was 3.6.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	-6.68	1	13.8		S
X <sub>2</sub> (Acidity)	-0.02	1	0.00		NS
X <sub>3</sub> (TOC)	-5.02	1	7.82		S
X <sub>1</sub> X <sub>2</sub>	-0.82	1	0.21		NS
X <sub>1</sub> X <sub>3</sub>	2.08	1	1.33		NS
X <sub>2</sub> X <sub>3</sub>	0.02	1	0.00		NS
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	1.28	1	0.50		NS
Error		8	12.9		

Table A32. ANOVA for Cd at 4 hours with SS304 well casing. The average normalized response was 117 and the standard deviation was 15.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	-15.2	1	4.26		NS
X <sub>2</sub> (Acidity)	28.9	1	15.4		S
X <sub>3</sub> (TOC)	-7.16	1	0.95		NS
X <sub>1</sub> X <sub>2</sub>	-16.7	1	5.11		NS
X <sub>1</sub> X <sub>3</sub>	5.14	1	0.49		NS
X <sub>2</sub> X <sub>3</sub>	-6.41	1	0.76		NS
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	3.09	1	0.18		NS
Error		8	217		



Table A33. ANOVA for Cd at 8 hours with SS304 well casing. The average normalized response was 116 and the standard deviation was 14.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	-18.9	1		6.86	S
X <sub>2</sub> (Acidity)	43.2	1		36.1	S
X <sub>3</sub> (TOC)	-5.35	1		0.55	NS
X <sub>1</sub> X <sub>2</sub>	-21.5	1		8.95	S
X <sub>1</sub> X <sub>3</sub>	2.42	1		0.11	NS
X <sub>2</sub> X <sub>3</sub>	-5.22	1		0.53	NS
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	5.00	1		0.48	NS
Error		8	207		

Table A34. ANOVA for Cd at 24 hours with SS304 well casing. The average normalized response was 112 and the standard deviation was 12.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	-24.6	1		16.4	S
X <sub>2</sub> (Acidity)	49.2	1		65.4	VS
X <sub>3</sub> (TOC)	-10.0	1		2.73	NS
X <sub>1</sub> X <sub>2</sub>	-24.3	1		16.0	S
X <sub>1</sub> X <sub>3</sub>	6.68	1		1.21	NS
X <sub>2</sub> X <sub>3</sub>	-10.7	1		3.07	NS
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	8.18	1		1.81	NS
Error		8	147		

Table A35. ANOVA for Cd at 72 hours with SS304 well casing. The average normalized response was 103 and the standard deviation was 14.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	-29.4	1		18.6	S
X <sub>2</sub> (Acidity)	44.8	1		43.3	S
X <sub>3</sub> (TOC)	-6.65	1		0.95	NS
X <sub>1</sub> X <sub>2</sub>	-31.0	1		20.7	S
X <sub>1</sub> X <sub>3</sub>	-0.00	1		0.00	NS
X <sub>2</sub> X <sub>3</sub>	-2.98	1		0.19	NS
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	4.22	1		0.38	NS
Error		8	186		

Table A36. ANOVA for Cd at 0.5 hours with SS316 well casing. The average normalized response was 104 and the standard deviation was 2.1.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	-5.69	1		29.0	S
X <sub>2</sub> (Acidity)	0.46	1		0.19	NS
X <sub>3</sub> (TOC)	-5.46	1		26.7	S
X <sub>1</sub> X <sub>2</sub>	-1.86	1		3.12	NS
X <sub>1</sub> X <sub>3</sub>	5.71	1		29.2	S
X <sub>2</sub> X <sub>3</sub>	0.51	1		0.24	NS
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	0.24	1		0.05	NS
Error		8	4.47		

Table A37. ANOVA for Cd at 4 hours with SS316 well casing. The average normalized response was 124 and the standard deviation was 49.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	-52.4	1		4.53	NS
X <sub>2</sub> (Acidity)	53.4	1		4.70	NS
X <sub>3</sub> (TOC)	-35.1	1		2.03	NS
X <sub>1</sub> X <sub>2</sub>	-47.5	1		3.72	NS
X <sub>1</sub> X <sub>3</sub>	38.0	1		2.38	NS
X <sub>2</sub> X <sub>3</sub>	-32.6	1		1.76	NS
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	34.7	1		1.99	NS
Error		8	2430		

Table A38. ANOVA for Cd at 8 hours with SS316 well casing. The average normalized response was 130 and the standard deviation was 47.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	-58.7	1		6.25	S
X <sub>2</sub> (Acidity)	69.7	1		8.80	S
X <sub>3</sub> (TOC)	-32.8	1		1.94	NS
X <sub>1</sub> X <sub>2</sub>	-57.5	1		5.99	S
X <sub>1</sub> X <sub>3</sub>	40.25	1		2.94	NS
X <sub>2</sub> X <sub>3</sub>	-33.7	1		2.06	NS
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	41.9	1		3.18	NS
Error		8	2210		

Table A39. ANOVA for Cd at 24 hours with SS316 well casing. The average normalized response was 136 and the standard deviation was 68.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	-73.6	1		4.70	NS
X <sub>2</sub> (Acidity)	78.2	1		5.31	NS
X <sub>3</sub> (TOC)	-45.9	1		1.83	NS
X <sub>1</sub> X <sub>2</sub>	-66.4	1		3.82	NS
X <sub>1</sub> X <sub>3</sub>	57.8	1		2.89	NS
X <sub>2</sub> X <sub>3</sub>	-57.6	1		2.88	NS
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	51.8	1		2.33	NS
Error		8	4610		

Table A40. ANOVA for Cd at 72 hours with SS316 well casing. The average normalized response was 125 and the standard deviation was 6.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	-76.8	1		5.34	S
X <sub>2</sub> (Acidity)	88.5	1		7.09	S
X <sub>3</sub> (TOC)	-47.0	1		2.00	NS
X <sub>1</sub> X <sub>2</sub>	-65.3	1		3.86	NS
X <sub>1</sub> X <sub>3</sub>	48.2	1		2.10	NS
X <sub>2</sub> X <sub>3</sub>	-51.3	1		2.38	NS
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	47.8	1		2.07	NS
Error		8	4420		

Table A41. ANOVA for Cr at 0.5 hours with PVC well casing. The average normalized response was 101 and the standard deviation was 1.8.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	-1.68	1		3.36	NS
X <sub>2</sub> (Acidity)	-1.45	1		2.52	NS
X <sub>3</sub> (TOC)	-1.72	1		3.36	NS
X <sub>1</sub> X <sub>2</sub>	1.88	1		4.21	NS
X <sub>1</sub> X <sub>3</sub>	0.90	1		0.97	NS
X <sub>2</sub> X <sub>3</sub>	1.08	1		1.39	NS
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	-1.50	1		2.70	NS
Error		8	3.34		

Table A42. ANOVA for Cr at 4 hours with PVC well casing. The average normalized response was 99.9 and the standard deviation was 1.3.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	0.96	1		2.15	NS
X <sub>2</sub> (Acidity)	0.62	1		0.90	NS
X <sub>3</sub> (TOC)	-1.06	1		2.62	NS
X <sub>1</sub> X <sub>2</sub>	-1.09	1		2.81	NS
X <sub>1</sub> X <sub>3</sub>	0.68	1		1.09	NS
X <sub>2</sub> X <sub>3</sub>	0.09	1		0.02	NS
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	-0.97	1		2.20	NS
Error		8	1.71		

Table A43. ANOVA for Cr at 8 hours with PVC well casing. The average normalized response was 100 and the standard deviation was 1.4.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	-1.44	1		4.21	NS
X <sub>2</sub> (Acidity)	0.71	1		1.04	NS
X <sub>3</sub> (TOC)	-1.33	1		3.65	NS
X <sub>1</sub> X <sub>2</sub>	-0.71	1		1.04	NS
X <sub>1</sub> X <sub>3</sub>	-1.41	1		4.07	NS
X <sub>2</sub> X <sub>3</sub>	1.99	1		8.05	S
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	-0.09	1		0.02	NS
Error		8	1.96		

Table A44. ANOVA for Cr at 24 hours with PVC well casing. The average normalized response was 100 and the standard deviation was 1.6.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	1.75	1		4.77	NS
X <sub>2</sub> (Acidity)	0.15	1		0.04	NS
X <sub>3</sub> (TOC)	-2.78	1		12.0	NS
X <sub>1</sub> X <sub>2</sub>	-0.10	1		0.02	NS
X <sub>1</sub> X <sub>3</sub>	-1.12	1		1.97	NS
X <sub>2</sub> X <sub>3</sub>	-0.48	1		0.35	NS
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	-0.08	1		0.01	NS
Error		8	2.57		

Table A45. ANOVA for Cr at 72 hours with PVC well casing. The average normalized response was 101 and the standard deviation was 1.8.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	2.71	1		8.80	S
X <sub>2</sub> (Acidity)	-1.39	1		2.30	NS
X <sub>3</sub> (TOC)	0.69	1		0.57	NS
X <sub>1</sub> X <sub>2</sub>	-1.11	1		1.48	NS
X <sub>1</sub> X <sub>3</sub>	1.01	1		1.23	NS
X <sub>2</sub> X <sub>3</sub>	1.21	1		1.76	NS
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	0.89	1		0.94	NS
Error		8	3.35		

Table A46. ANOVA for Cr at 0.5 hours with PTFE well casing. The average normalized response was 101 and the standard deviation was 0.7.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	0.30	1		0.70	NS
X <sub>2</sub> (Acidity)	-0.78	1		4.68	NS
X <sub>3</sub> (TOC)	-0.12	1		0.12	NS
X <sub>1</sub> X <sub>2</sub>	0.72	1		4.10	NS
X <sub>1</sub> X <sub>3</sub>	0.62	1		3.05	NS
X <sub>2</sub> X <sub>3</sub>	-0.45	1		1.58	NS
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	-0.45	1		1.58	NS
Error		8	0.51		

Table A47. ANOVA for Cr at 4 hours with PTFE well casing. The average normalized response was 101 and the standard deviation was 1.1.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	1.49	1		7.73	S
X <sub>2</sub> (Acidity)	0.98	1		3.33	NS
X <sub>3</sub> (TOC)	1.47	1		7.47	S
X <sub>1</sub> X <sub>2</sub>	-0.13	1		0.06	NS
X <sub>1</sub> X <sub>3</sub>	-0.97	1		3.25	NS
X <sub>2</sub> X <sub>3</sub>	1.09	1		4.14	NS
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	-1.49	1		7.73	S
Error		8	1.16		

Table A48. ANOVA for Cr at 8 hours with PTFE well casing. The average normalized response was 98.9 and the standard deviation was 1.9.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	-3.16	1		11.0	S
X <sub>2</sub> (Acidity)	-0.79	1		0.68	NS
X <sub>3</sub> (TOC)	-1.46	1		2.35	NS
X <sub>1</sub> X <sub>2</sub>	-3.21	1		11.3	S
X <sub>1</sub> X <sub>3</sub>	2.26	1		5.62	S
X <sub>2</sub> X <sub>3</sub>	4.49	1		22.1	S
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	1.41	1		2.19	NS
Error		8	3.64		

Table A49. ANOVA for Cr at 24 hours with PTFE well casing. The average normalized response was 101 and the standard deviation was 2.4.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	-3.16	1	11.0	S	
X <sub>2</sub> (Acidity)	0.28	1	0.05	NS	
X <sub>3</sub> (TOC)	-1.22	1	1.06	NS	
X <sub>1</sub> X <sub>2</sub>	0.00	1	0.00	NS	
X <sub>1</sub> X <sub>3</sub>	-0.95	1	0.63	NS	
X <sub>2</sub> X <sub>3</sub>	-1.00	1	0.71	NS	
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	-1.98	1	2.77	NS	
Error		8	5.64		

Table A50. ANOVA for Cr at 72 hours with PTFE well casing. The average normalized response was 100 and the standard deviation was 1.3.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	3.59	1	31.8	S	
X <sub>2</sub> (Acidity)	-1.19	1	3.49	NS	
X <sub>3</sub> (TOC)	0.74	1	1.35	NS	
X <sub>1</sub> X <sub>2</sub>	-0.21	1	0.11	NS	
X <sub>1</sub> X <sub>3</sub>	-2.14	1	11.3	S	
X <sub>2</sub> X <sub>3</sub>	0.84	1	1.74	NS	
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	-0.79	1	1.53	NS	
Error		8	1.62		

Table A51. ANOVA for Cr at 0.5 hours with SS304 well casing. The average normalized response was 101 and the standard deviation was 1.6.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	-0.99	1	1.50	NS	
X <sub>2</sub> (Acidity)	-1.19	1	2.16	NS	
X <sub>3</sub> (TOC)	-0.09	1	0.01	NS	
X <sub>1</sub> X <sub>2</sub>	0.71	1	0.78	NS	
X <sub>1</sub> X <sub>3</sub>	1.01	1	1.57	NS	
X <sub>2</sub> X <sub>3</sub>	-0.64	1	0.62	NS	
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	-0.29	1	0.13	NS	
Error		8	2.61		

Table A52. ANOVA for Cr at 4 hours with SS304 well casing. The average normalized response was 95.7 and the standard deviation was 3.7.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	-1.39	1	0.56	NS	
X <sub>2</sub> (Acidity)	-7.14	1	14.7	S	
X <sub>3</sub> (TOC)	1.96	1	1.11	NS	
X <sub>1</sub> X <sub>2</sub>	-2.11	1	1.29	NS	
X <sub>1</sub> X <sub>3</sub>	-0.81	1	0.19	NS	
X <sub>2</sub> X <sub>3</sub>	-0.86	1	0.22	NS	
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	-2.94	1	2.50	NS	
Error		8	13.8		

Table A53. ANOVA for Cr at 8 hours with SS304 well casing. The average normalized response was 97.2 and the standard deviation was 16.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	-10.7	1	1.83	NS	
X <sub>2</sub> (Acidity)	-5.16	1	0.42	NS	
X <sub>3</sub> (TOC)	8.26	1	1.09	NS	
X <sub>1</sub> X <sub>2</sub>	-9.66	1	1.48	NS	
X <sub>1</sub> X <sub>3</sub>	-10.6	1	1.80	NS	
X <sub>2</sub> X <sub>3</sub>	9.76	1	1.52	NS	
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	9.79	1	1.52	NS	
Error		8	251		

Table 54. ANOVA for Cr at 24 hours with SS304 well casing. The average normalized response was 103 and the standard deviation was 37.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	-7.74	1	0.17	NS	
X <sub>2</sub> (Acidity)	3.46	1	0.03	NS	
X <sub>3</sub> (TOC)	20.3	1	1.20	NS	
X <sub>1</sub> X <sub>2</sub>	-11.0	1	0.35	NS	
X <sub>1</sub> X <sub>3</sub>	-18.6	1	1.00	NS	
X <sub>2</sub> X <sub>3</sub>	19.2	1	1.07	NS	
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	-20.9	1	1.26	NS	
Error		8	1380		

Table A55. ANOVA for Cr at 72 hours with SS304 well casing. The average normalized response was 103 and the standard deviation was 42.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	5.50	1	0.07	NS	
X <sub>2</sub> (Acidity)	5.88	1	0.08	NS	
X <sub>3</sub> (TOC)	32.8	1	2.39	NS	
X <sub>1</sub> X <sub>2</sub>	1.25	1	0.00	NS	
X <sub>1</sub> X <sub>3</sub>	-18.9	1	0.79	NS	
X <sub>2</sub> X <sub>3</sub>	29.6	1	1.94	NS	
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	-15.8	1	0.56	NS	
Error		8	1800		

Table A56. ANOVA for Cr at 0.5 hours with SS316 well casing. The average normalized response was 102 and the standard deviation was 1.5.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	-1.51	1	4.43	NS	
X <sub>2</sub> (Acidity)	-1.49	1	4.17	NS	
X <sub>3</sub> (TOC)	0.59	1	0.65	NS	
X <sub>1</sub> X <sub>2</sub>	-0.34	1	0.21	NS	
X <sub>1</sub> X <sub>3</sub>	1.69	1	5.37	S	
X <sub>2</sub> X <sub>3</sub>	-0.49	1	0.45	NS	
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	-0.89	1	1.48	NS	
Error		8	2.12		

Table A57. ANOVA for Cr at 4 hours with SS316 well casing. The average normalized response was 92.1 and the standard deviation was 5.2.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	-6.54	1	6.20	S	
X <sub>2</sub> (Acidity)	-10.3	1	15.4	S	
X <sub>3</sub> (TOC)	10.0	1	14.6	S	
X <sub>1</sub> X <sub>2</sub>	-5.99	1	5.20	NS	
X <sub>1</sub> X <sub>3</sub>	0.11	1	0.00	NS	
X <sub>2</sub> X <sub>3</sub>	6.54	1	6.20	S	
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	0.11	1	0.00	NS	
Error		8	27.6		

Table A58. ANOVA for Cr at 8 hours with SS316 well casing. The average normalized response was 87.2 and the standard deviation was 10.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	-14.1	1	7.77	S	
X <sub>2</sub> (Acidity)	-15.6	1	9.56	S	
X <sub>3</sub> (TOC)	11.8	1	5.46	S	
X <sub>1</sub> X <sub>2</sub>	-9.19	1	3.32	NS	
X <sub>1</sub> X <sub>3</sub>	-1.59	1	0.10	NS	
X <sub>2</sub> X <sub>3</sub>	10.6	1	4.42	NS	
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	1.99	1	0.15	NS	
Error		8	102		

Table A59. ANOVA for Cr at 24 hours with SS316 well casing. The average normalized response was 85.5 and the standard deviation was 11.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	-9.91	1	3.32	NS	
X <sub>2</sub> (Acidity)	-22.4	1	17.0	S	
X <sub>3</sub> (TOC)	17.4	1	10.2	S	
X <sub>1</sub> X <sub>2</sub>	-11.9	1	4.77	NS	
X <sub>1</sub> X <sub>3</sub>	-1.71	1	0.10	NS	
X <sub>2</sub> X <sub>3</sub>	11.4	1	4.42	NS	
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	2.26	1	0.17	NS	
Error		8	118		

Table A60. ANOVA for Cr at 72 hours with SS316 well casing. The average normalized response was 83.6 and the standard deviation was 9.9.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	-5.86	1	1.39	NS	
X <sub>2</sub> (Acidity)	-22.6	1	20.7	S	
X <sub>3</sub> (TOC)	18.8	1	14.3	S	
X <sub>1</sub> X <sub>2</sub>	-7.66	1	2.38	NS	
X <sub>1</sub> X <sub>3</sub>	-2.36	1	0.23	NS	
X <sub>2</sub> X <sub>3</sub>	12.9	1	6.77	S	
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	3.64	1	0.54	NS	
Error		8	98.6		

Table A61. ANOVA for Pb at 0.5 hours with PVC well casing. The average normalized response was 99.9 and the standard deviation was 0.9.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	-0.09	1	0.04	NS	
X <sub>2</sub> (Acidity)	-1.06	1	5.52	S	
X <sub>3</sub> (TOC)	-0.61	1	1.83	NS	
X <sub>1</sub> X <sub>2</sub>	0.74	1	2.66	NS	
X <sub>1</sub> X <sub>3</sub>	2.09	1	21.3	S	
X <sub>2</sub> X <sub>3</sub>	-0.04	1	0.01	NS	
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	-0.84	1	3.43	NS	
Error		8	0.92		

Table A62. ANOVA for Pb at 4 hours with PVC well casing. The average normalized response was 88.9 and the standard deviation was 3.0.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	-0.71	1	0.22	NS	
X <sub>2</sub> (Acidity)	-4.16	1	7.54	S	
X <sub>3</sub> (TOC)	5.89	1	15.1	S	
X <sub>1</sub> X <sub>2</sub>	2.34	1	2.37	NS	
X <sub>1</sub> X <sub>3</sub>	-3.21	1	4.49	NS	
X <sub>2</sub> X <sub>3</sub>	4.84	1	10.2	S	
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	-1.71	1	1.28	NS	
Error		8	9.19		

Table A63. ANOVA for Pb at 8 hours with PVC well casing. The average normalized response was 89.3 and the standard deviation was 3.5.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	-2.96	1	2.84	NS	
X <sub>2</sub> (Acidity)	-0.06	1	0.00	NS	
X <sub>3</sub> (TOC)	7.46	1	18.0	S	
X <sub>1</sub> X <sub>2</sub>	-0.79	1	0.20	NS	
X <sub>1</sub> X <sub>3</sub>	-0.41	1	0.06	NS	
X <sub>2</sub> X <sub>3</sub>	3.64	1	4.27	NS	
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	-2.54	1	2.08	NS	
Error		8	12.4		

Table A64. ANOVA for Pb at 24 hours with PVC well casing. The average normalized response was 80.8 and the standard deviation was 5.1.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	-2.78	1	1.20	NS	
X <sub>2</sub> (Acidity)	-10.7	1	17.9	S	
X <sub>3</sub> (TOC)	13.9	1	30.1	S	
X <sub>1</sub> X <sub>2</sub>	0.30	1	0.01	NS	
X <sub>1</sub> X <sub>3</sub>	-3.55	1	1.96	NS	
X <sub>2</sub> X <sub>3</sub>	7.95	1	9.81	S	
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	-2.68	1	1.11	NS	
Error		8	25.7		

Table A65. ANOVA for Pb at 72 hours with PVC well casing. The average normalized response was 74.3 and the standard deviation was 6.4.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	0.20	1		0.00	NS
X <sub>2</sub> (Acidity)	-11.7	1		13.3	S
X <sub>3</sub> (TOC)	19.2	1		35.7	S
X <sub>1</sub> X <sub>2</sub>	1.67	1		0.27	NS
X <sub>1</sub> X <sub>3</sub>	-2.75	1		0.73	NS
X <sub>2</sub> X <sub>3</sub>	8.02	1		6.23	S
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	-2.98	1		0.86	NS
Error		8	41.4		

Table A66. ANOVA for Pb at 0.5 hours with PTFE well casing. The average normalized response was 100 and the standard deviation was 2.6.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	0.12	1		0.01	NS
X <sub>2</sub> (Acidity)	1.25	1		0.96	NS
X <sub>3</sub> (TOC)	0.92	1		0.52	NS
X <sub>1</sub> X <sub>2</sub>	-0.08	1		0.00	NS
X <sub>1</sub> X <sub>3</sub>	1.40	1		1.20	NS
X <sub>2</sub> X <sub>3</sub>	0.28	1		0.05	NS
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	-1.95	1		2.32	NS
Error		8	6.53		

Table A67. ANOVA for Pb at 4 hours with PTFE well casing. The average normalized response was 97.4 and the standard deviation was 1.9.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	3.30	1		11.8	S
X <sub>2</sub> (Acidity)	0.88	1		0.83	NS
X <sub>3</sub> (TOC)	-0.42	1		0.20	NS
X <sub>1</sub> X <sub>2</sub>	3.28	1		11.6	S
X <sub>1</sub> X <sub>3</sub>	-4.52	1		22.3	S
X <sub>2</sub> X <sub>3</sub>	-2.65	1		7.61	S
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	-2.30	1		5.73	S
Error		8	3.69		

Table A68. ANOVA for Pb at 8 hours with PTFE well casing. The average normalized response was 98.5 and the standard deviation was 3.2.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	1.24	1		0.61	NS
X <sub>2</sub> (Acidity)	3.84	1		5.90	S
X <sub>3</sub> (TOC)	0.66	1		0.18	NS
X <sub>1</sub> X <sub>2</sub>	-3.21	1		4.13	NS
X <sub>1</sub> X <sub>3</sub>	-0.09	1		0.00	NS
X <sub>2</sub> X <sub>3</sub>	-1.49	1		0.89	NS
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	2.11	1		1.79	NS
Error		8	9.98		

Table A69. ANOVA for Pb at 24 hours with PTFE well casing. The average normalized response was 95.1 and the standard deviation was 4.0.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	0.08	1		0.00	NS
X <sub>2</sub> (Acidity)	-2.75	1		1.86	NS
X <sub>3</sub> (TOC)	4.75	1		5.56	S
X <sub>1</sub> X <sub>2</sub>	-3.38	1		2.81	NS
X <sub>1</sub> X <sub>3</sub>	-0.68	1		0.11	NS
X <sub>2</sub> X <sub>3</sub>	-0.25	1		0.02	NS
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	-0.48	1		0.06	NS
Error		8	16.2		

Table A70. ANOVA for Pb at 72 hours with PTFE well casing. The average normalized response was 89.9 and the standard deviation was 3.4.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	5.96	1		12.3	NS
X <sub>2</sub> (Acidity)	-4.49	1		6.99	S
X <sub>3</sub> (TOC)	8.16	1		23.1	S
X <sub>1</sub> X <sub>2</sub>	-1.21	1		0.51	NS
X <sub>1</sub> X <sub>3</sub>	-1.51	1		0.79	NS
X <sub>2</sub> X <sub>3</sub>	0.94	1		0.31	NS
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	-2.89	1		2.90	NS
Error		8	11.5		

Table A71. ANOVA for Pb at 0.5 hours with SS304 well casing. The average normalized response was 102 and the standard deviation was 0.8.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	0.05	1		0.02	NS
X <sub>2</sub> (Acidity)	0.50	1		1.57	NS
X <sub>3</sub> (TOC)	0.08	1		0.04	NS
X <sub>1</sub> X <sub>2</sub>	-0.82	1		4.26	NS
X <sub>1</sub> X <sub>3</sub>	-0.35	1		0.77	NS
X <sub>2</sub> X <sub>3</sub>	-0.80	1		4.01	NS
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	0.52	1		1.73	NS
Error		8	0.64		

Table A72. ANOVA for Pb at 4 hours with SS304 well casing. The average normalized response was 78.4 and the standard deviation was 3.5.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	-4.48	1		6.61	S
X <sub>2</sub> (Acidity)	13.5	1		60.6	VS
X <sub>3</sub> (TOC)	12.9	1		55.1	VS
X <sub>1</sub> X <sub>2</sub>	1.90	1		1.19	NS
X <sub>1</sub> X <sub>3</sub>	-2.58	1		2.19	NS
X <sub>2</sub> X <sub>3</sub>	-5.15	1		8.75	S
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	-0.85	1		0.24	NS
Error		8	12.1		

Table A73. ANOVA for Pb at 8 hours with SS304 well casing. The average normalized response was 69.9 and the standard deviation was 3.1.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	-6.76	1	19.0	S	
X <sub>2</sub> (Acidity)	24.2	1	243	VS	
X <sub>3</sub> (TOC)	118.0	1	134	VS	
X <sub>1</sub> X <sub>2</sub>	-5.01	1	10.5	S	
X <sub>1</sub> X <sub>3</sub>	-2.09	1	1.81	NS	
X <sub>2</sub> X <sub>3</sub>	-6.61	1	18.2	S	
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	0.26	1	0.03	NS	
Error		8	9.61		

Table A77. ANOVA for Pb at 4 hours with SS316 well casing. The average normalized response was 80.3 and the standard deviation was 7.7.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	-11.0	1	8.14	S	
X <sub>2</sub> (Acidity)	14.4	1	13.8	S	
X <sub>3</sub> (TOC)	14.8	1	14.7	S	
X <sub>1</sub> X <sub>2</sub>	-2.25	1	0.34	NS	
X <sub>1</sub> X <sub>3</sub>	0.80	1	0.04	NS	
X <sub>2</sub> X <sub>3</sub>	-5.05	1	1.71	NS	
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	6.12	1	2.51	NS	
Error		8	59.7		

Table A74. ANOVA for Pb at 24 hours with SS304 well casing. The average normalized response was 53.8 and the standard deviation was 4.2.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	-4.04	1	3.67	NS	
X <sub>2</sub> (Acidity)	30.4	1	209	VS	
X <sub>3</sub> (TOC)	26.6	1	161	VS	
X <sub>1</sub> X <sub>2</sub>	-4.74	1	5.09	NS	
X <sub>1</sub> X <sub>3</sub>	-6.39	1	9.26	S	
X <sub>2</sub> X <sub>3</sub>	-0.26	1	0.02	NS	
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	-1.89	1	0.81	NS	
Error		8	17.6		

Table A78. ANOVA for Pb at 8 hours with SS316 well casing. The average normalized response was 80.4 and the standard deviation was 10.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	-15.4	1	9.47	S	
X <sub>2</sub> (Acidity)	21.5	1	18.4	S	
X <sub>3</sub> (TOC)	19.4	1	15.0	S	
X <sub>1</sub> X <sub>2</sub>	-7.75	1	2.39	NS	
X <sub>1</sub> X <sub>3</sub>	4.02	1	0.64	NS	
X <sub>2</sub> X <sub>3</sub>	-4.38	1	0.76	NS	
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	2.00	1	0.16	NS	
Error		8	101		

Table A75. ANOVA for Pb at 72 hours with SS304 well casing. The average normalized response was 45.2 and the standard deviation was 6.1.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	-0.78	1	0.06	NS	
X <sub>2</sub> (Acidity)	31.4	1	106	VS	
X <sub>3</sub> (TOC)	24.8	1	65.8	VS	
X <sub>1</sub> X <sub>2</sub>	-0.18	1	0.00	NS	
X <sub>1</sub> X <sub>3</sub>	-3.65	1	1.43	NS	
X <sub>2</sub> X <sub>3</sub>	3.72	1	1.49	NS	
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	-2.30	1	0.57	NS	
Error		8	37.3		

Table A79. ANOVA for Pb at 24 hours with SS316 well casing. The average normalized response was 79.3 and the standard deviation was 19.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	-21.4	1	5.23	NS	
X <sub>2</sub> (Acidity)	17.7	1	3.58	NS	
X <sub>3</sub> (TOC)	29.6	1	10.0	S	
X <sub>1</sub> X <sub>2</sub>	-5.02	1	0.29	NS	
X <sub>1</sub> X <sub>3</sub>	2.60	1	0.08	NS	
X <sub>2</sub> X <sub>3</sub>	3.20	1	0.11	NS	
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	-0.40	1	0.00	NS	
Error		8	351		

Table A76. ANOVA for Pb at 0.5 hours with SS316 well casing. The average normalized response was 101 and the standard deviation was 2.5.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	-2.51	1	3.89	NS	
X <sub>2</sub> (Acidity)	0.31	1	0.06	NS	
X <sub>3</sub> (TOC)	1.06	1	0.69	NS	
X <sub>1</sub> X <sub>2</sub>	-0.64	1	0.25	NS	
X <sub>1</sub> X <sub>3</sub>	1.01	1	0.63	NS	
X <sub>2</sub> X <sub>3</sub>	-0.01	1	0.00	NS	
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	0.86	1	0.46	NS	
Error		8	6.49		

Table A80. ANOVA for Pb at 72 hours with SS316 well casing. The average normalized response was 72.0 and the standard deviation was 17.

Factor	Effects	df	MS	F	Sig
X <sub>1</sub> (Metal conc)	-2.65	1	0.10	NS	
X <sub>2</sub> (Acidity)	32.5	1	14.4	S	
X <sub>3</sub> (TOC)	35.0	1	16.7	S	
X <sub>1</sub> X <sub>2</sub>	0.80	1	0.01	NS	
X <sub>1</sub> X <sub>3</sub>	6.40	1	0.56	NS	
X <sub>2</sub> X <sub>3</sub>	-6.82	1	0.64	NS	
X <sub>1</sub> X <sub>2</sub> X <sub>3</sub>	-1.70	1	0.04	NS	
Error		8	293		